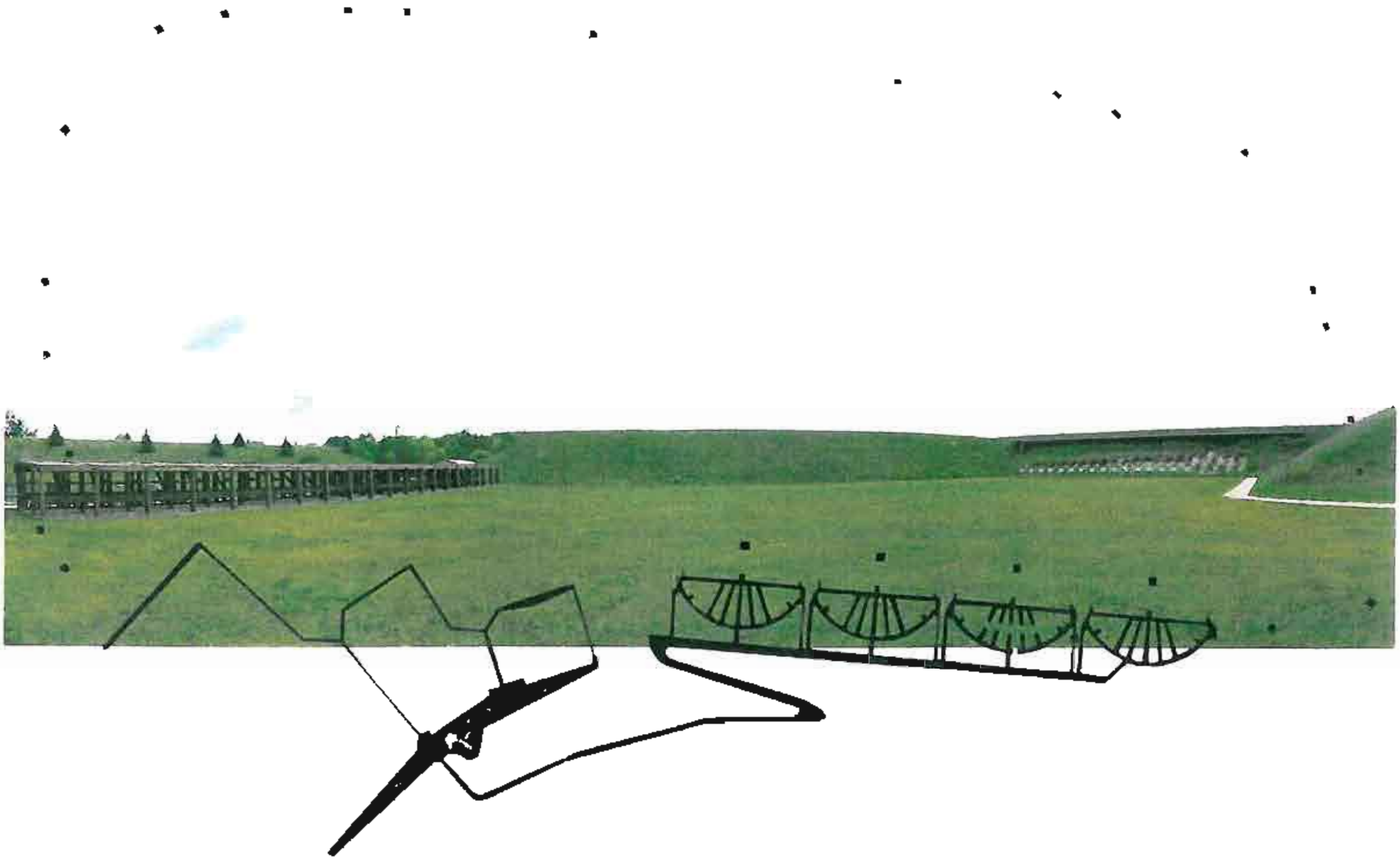
Sound Assessment and Analysis for the Island Lake Recreation Area Shooting Ranges

for:

State of Michigan Department of Natural Resources, P.O. Box 30028 Lansing, MI 48909

September 30, 2008



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for the

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Brighton, Michigan

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P.O. Box 30028
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by

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INTRODUCTION

This report contains the sound assessment and analysis for the Island Lake Recreation Area Shooting Range in Brighton, Michigan. Acoustical measurements of sound levels from various shooting events were recorded at multiple locations on site and in the surrounding community at locations selected by DNR over a three week period in June, 2008. Acoustical measurements of actual shooting range events on the Sporting Clay Range, Trap and Skeet Range, and Rifle and Pistol Ranges were made as part of a series of controlled studies to isolate the acoustical impact of shooting positions within each shooting range on residential receivers to the north and south of the facility, to quantify the gunfire sound levels at surrounding residential receivers, and to quantify the performance of existing sound reduction features such as the partial shed enclosures around the Sporting Clay Range stations. Long term measurements of sound levels in the community and short term measurements of specific acoustical events during an actual competition day were also made. The data collected during the studies were used in computer models to assess various sound reduction schemes for each of the ranges.

This report contains a discussion of the measurement procedure; an interpretation of the sound levels recorded during the site visits; presentation of sound levels of specific shooting events from specific locations on site to specific locations in the surrounding neighborhoods; and recommendations to reduce the sound levels from range events in the surrounding neighborhoods.

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EXECUTIVE SUMMARY

Siebein Associates, Inc., performed acoustical measurements at locations in and around the Island Lake Recreation Area Shooting Ranges in Brighton, Michigan during the month of June, 2008 during periods of normal range usage and during a Saturday sporting clays tournament. A series of controlled studies and experiments were conducted to better understand the level and character of sound which emanates from the shooting ranges, the impact on local residents, and to determine sound reduction possibilities for the ranges. The data from the measured activities at the site were used in computer models to assess the acoustic reductions possible from a number of sound reduction options. The major findings of the study are listed below.

1. **Sound levels from guns fired during the Sporting Clay Range studies were measured at levels of 44 to 64 dBA at residential receiver locations approximately 1 to 1.5 miles north (R1 and R2) of the Ranges and 46 to 61 dBA at a residential receiver location approximately 1.25 miles south/southeast of the Ranges (R3).** At times these levels exceeded the ambient sounds by as much as 15 to 20 dBA. Sound levels from Trap and Skeet activities measured at Locations R1 and R2 were in the 43 to 54 dBA range and sound levels from the Rifle and Pistol Range activities were in the 46 to 62 dBA range. Under adverse weather conditions, these levels could increase by as much as 10 to 15 dB more.

2. **Sound levels measured at distant residential receiver locations (R1, R2, and R3) from guns fired during the Competition on Saturday, June 21, 2008 were significantly higher than those measured during the controlled studies.** Of the 400 shots fired during the controlled studies, only four exceeded 60 dBA, and the highest was 64 dBA. In contrast, during a typical half hour during the afternoon of the Competition, sound levels from guns measured at Location R3 were routinely above 60 dBA, with several shots as high as 70 to 75 dBA.

3. **Acoustically adverse weather conditions can have a significant effect on sound levels measured at receiver locations that are far from the source.** Temperature inversions (warmer air up high) can increase sound levels at distances greater than 1000 ft by as much as 10 dB, and temperature lapses (warmer air nearer to the ground) can decrease sound levels measured at distances greater than 1,000 ft by as much as 10 dB. Similarly, sounds will be measured higher when the receiver is downwind of the source and lower when the receiver is upwind of the source by approximately +/- 5 dBA, compared to when there is no wind at all. Loss of leaves on trees in the winter will also allow sounds to propagate at higher levels to remote receivers.

4. **A full building enclosure is required for each of the three ranges to reduce the sounds of gunfire to the vicinity of the ambient sound levels at the residential receivers studied to the north and south of the site.** The results of measurements made during the controlled studies and the Competition day, as well as a review of data contained in reports by other consultants taken during different times of year, indicates that gunfire sounds from the Ranges, under relatively neutral atmospheric conditions (i.e., minimal wind and temperature gradients) typically exceed the ambient sound levels at remote residential receivers by approximately 5 to 15 dBA, and under acoustically adverse atmospheric conditions (i.e., moderate to high winds, temperature inversions, etc.) and or winter conditions with no foliage on the trees, exceed the ambient sound levels by as much as 20 to 25 dBA or higher.

5. **Future action for the DNR to consider includes evaluating the cost effectiveness of the options presented in this report, including the construction of full building enclosures for the ranges.**

6. **The construction of tall berms or barrier walls around the ranges and downrange of the shooters provide only a 0 to 3 dB insertion loss at the large distances between the Ranges and the affected receiver locations.** Computer model studies showed that depressing the north half of the sporting clay range 20 ft and constructing a 40 ft high berm between the shooters and residential receivers to the south provides only a 3 dB reduction in sound levels, which is a perceivable reduction in sound level to people with normal hearing sensitivities. The cost to construct a berm of this magnitude may not be able to be justified given the relatively small acoustical impact it will have. It takes a 10 dB or greater reduction for sounds to be heard as ½ as loud as they previously were by people of normal sensitivities.

7. **Eliminating, moving and/or rotating select Sporting Clay Range stations so that they have a more east-west orientation is the only other practical way to achieve significant reductions in sounds from specific stations outside of a full building enclosure.** Due to site constraints, reorienting more than a select few of the stations may not be possible. Included in the report are suggestions for relocating, eliminating, and rotating select stations to reduce the sounds of gunfire on surrounding residences that are currently subjected to the most sound. The Michigan Department of Natural Resources will need to evaluate the number of stations necessary to operate a viable course.

8. **Create sound absorbing shooting lanes at the Rifle and Pistol Range as described in the text.** Consider mocking up these partial enclosures in just a few lanes and conducting field tests to evaluate their effectiveness. This would be a relatively low cost experiment option that could produce reductions on the order of 2 to 4 dB, which would be noticeable to people of normal hearing sensitivities.

9. **The findings of the study are limited to the results of acoustical measurements made during the specific time of year and under the specific weather conditions that existed during the site visits.** The acoustical measurements occurred during the time of year when there is peak foliage on the trees, when wind speed was relatively low, and when temperature inversions did not appear to be present. Sound levels during fall and winter months when the foliage has fallen from trees, or during periods of greater wind or temperature inversions may result in higher gunfire sound levels at residential receivers, similar to those measured by other consultants.

THE SOUNDS OF BRIGHTON

The ambient sound levels in a community are a result of complex interactions of multiple sound sources with different frequency (or pitch) components that occur for varying periods of time from all of the activities that occur in a suburban area. How these sounds combine over the course of a day to determine the ambient sound level and what the relative contribution of each sound source is to the total overall level is a complex undertaking.

As Brighton and the surrounding towns and villages have grown, the variety of sounds that bring life to the town has increased as well. The ambient sound is comprised of the sounds of a growing suburban community. Traffic on Interstate 96 is heard throughout the area at all times of the day and night. Planes are frequently heard flying overhead. Automotive traffic mixed with gravel trucks and other commercial vehicles on the main roads such as Kensington Road and Silver Lake Road, and secondary roads such as Spencer Road and Dixboro Road is also heard in the background. As the weather heats up, air conditioning units in neighbors yards come on. The sounds from construction on the many new homes being built in the area such as the pounding of hammers on nails and earth moving equipment is heard throughout many neighborhoods. The breezes blowing in through the lush early summer foliage, and a constant chorus of the songs of large numbers of birds, the buzzing of insects and croaking of frogs are also heard at all locations.

Many people in the neighborhoods around Brighton work during the day. There are few sounds within the residential neighborhoods other than traffic on roads in the distance, birds chirping, planes flying overhead, and construction and delivery trucks during day time hours.

In the afternoons and weekends the neighborhoods come alive. Large numbers of people use the recreational facilities at the Metropark and Island Lake Recreation Areas, birds chirp in the trees overhead, breezes blow through the trees, insects croak loudly in the night and evening hours, people drive home from work and run errands on busy roads and homeowners move into their yards to cut the grass, build a deck or play with their children.

PROBLEM STATEMENT

The State of Michigan Department of Natural Resources (DNR) and a private concessionaire operate a public shooting range located in the Island Lake Recreation Area in Livingston County, Michigan. The shooting ranges consist specifically of 25-Yard, 50-Yard, and 100-Yard Rifle and Pistol Ranges, four Trap and Skeet Ranges, and a 28 station Sporting Clay Range, of which only 15 to 18 stations are typically used. Sounds from shooting activities taking place at the Island Lake Recreation Area Shooting Range have been the source of complaints and litigation by residents surrounding the Ranges for many years. Although the Livingston County Circuit Court ruled in September 2007 that "the activities of the (clay target concessionaire) do not constitute a nuisance under Michigan law," the Michigan Department of Natural resources commissioned Siebein Associates, Inc., to prepare this Sound Assessment and Analysis to analyze the sounds from the Ranges and explore sound reduction strategies to reduce the sound from shooting stations and shotgun activities.

METHOD

Siebein Associates, Inc., undertook a series of controlled shooting range studies to isolate the acoustic impact of shooting positions within each shooting range on residential receivers to the north and south of the range, to quantify the level of gunfire sounds on surrounding residential receivers, and to quantify the performance of existing sound reduction features such as the partial shed enclosures around the Sporting Clay Range stations. The data collected during the studies were used in computer models to assess varioussound reduction schemes for each of the ranges.

The general method for the Sound Assessment and Analysis consists of the items listed below. Specific details on methods used to acquire data for each of the Range Studies and Experiments are included in Appendix A.

1. Take long term average sound level measurements at locations around the Island Lakes Shooting Range site to determine the character and magnitude of existing sounds in the community.

2. Take short term average sound level measurements of specific acoustic events at locations around the Island Lake Shooting Range site to document the loudness and frequency content or pitch of the combinations of sounds that characterize the sonic environment in the neighborhoods surrounding the site.

3. Take acoustical measurements of various range activities including typical days of range usage, a Saturday Sporting Clays tournament and a series of experiments intended to isolate the contribution of each of the ranges to specific locations in the surrounding community.

4. Sound levels from individual gunshots measured during the shooting range studies were compared to the ambient sound levels to determine the magnitude of the gunfire sounds at critical receiver locations. These data were also used to quantify:

    A. The directional characteristics of a typical 12 gauge shotgun used for sporting clay and trap and skeet activities.
    B. Differences in sound levels relative to changes in the horizontal angle of gunfire.
    C. Difference in sound level relative to changes in the vertical angle of gunfire.
    D. The insertion loss (i.e., sound reduction) of the partial shed enclosures surrounding the sporting clay stations.
    E. The insertion loss of the overhead baffle system at the Rifle and Pistol Ranges.

5. Computer models were constructed to quantify the magnitude of sound reduction for various sound reduction options developed for each of the ranges, including increased berm height, partial enclosures, and changes in the direction of fire for specific shooting stations, taking into account the distances, topography, vegetation and limitations due to sky reflections that occur at the site.

DESCRIPTIONS OF MEASUREMENT LOCATIONS

Figure 1 contains an aerial map of the Island Lake Shooting Range and surrounding area identifying the location where acoustical measurements were conducted. Short term measurements of specific acoustic events during range studies on June 3 and June 10, 2008 and during the competition on June 21, 2008 were made at locations R1, R2, R3, and R4. Long term measurements of ambient sound levels were made at locations R1 through R7.

Figure 2 contains an aerial map of the Island Lake Recreation Area Shooting Ranges, with each range identified, along with the heights of the key berms surrounding portions of the site.

R1 Location R1 was located at 13301 Lashbrook Lane East, Brighton Township. The sound level meter was located near the horse paddock in the back yard. This location is approximately 1.15 miles N/NW of the Shooting Range Clubhouse.

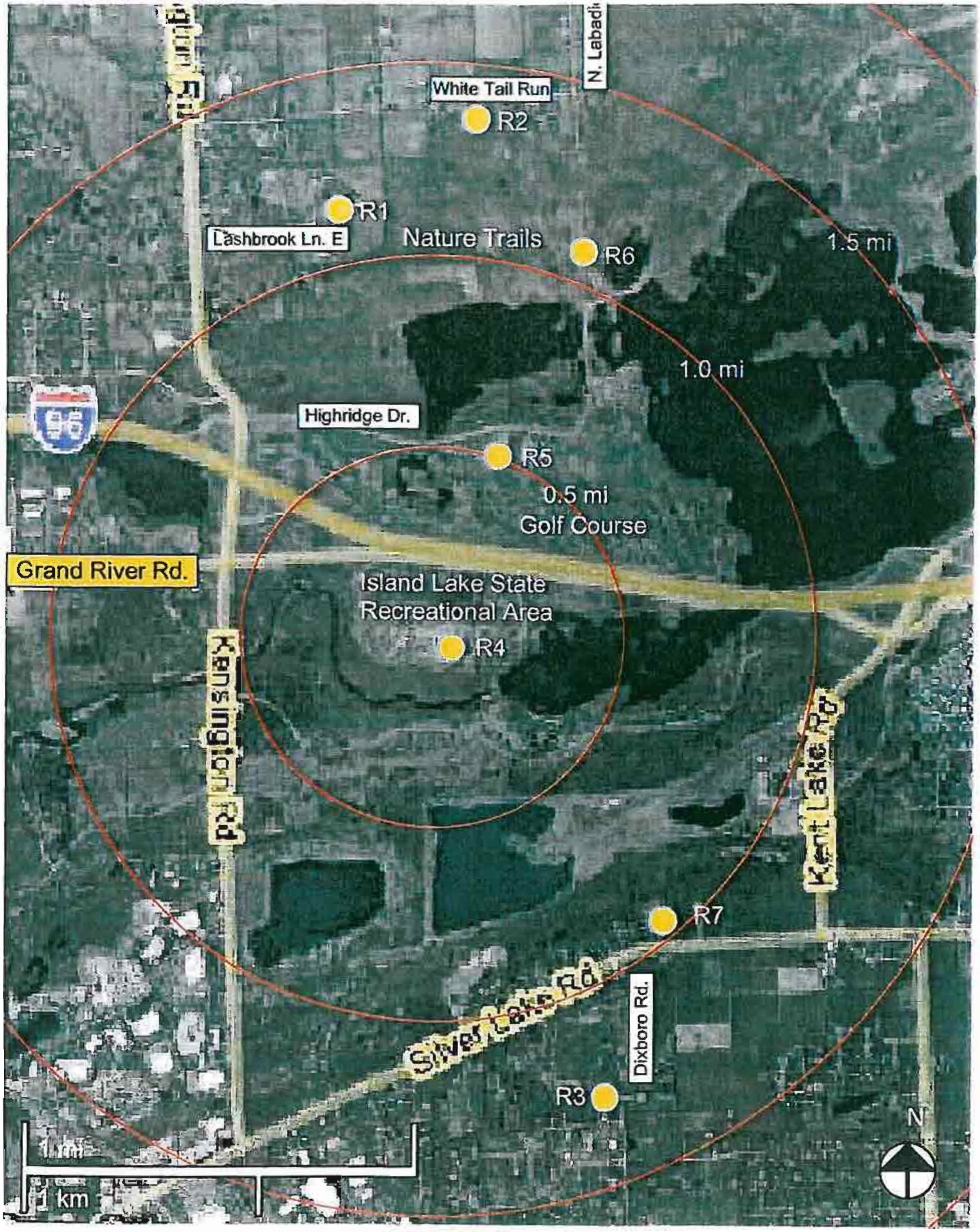

Figure 1. Aerial map showing acoustical measurement locations used in the Sound Assessment and Analysis.

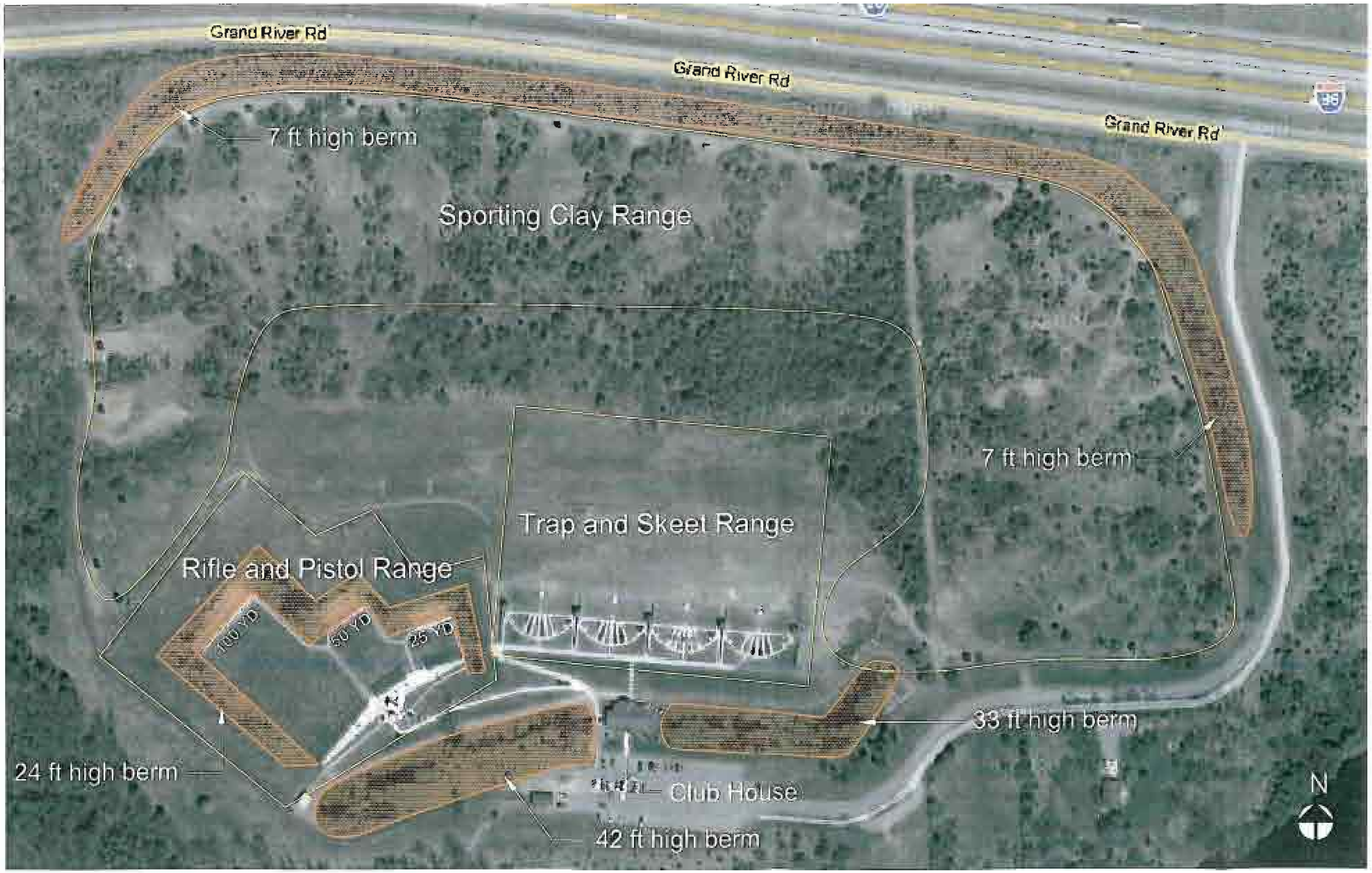

Figure 2. Aerial map of the Island Lake Recreation Area Shooting Ranges.

R2 Location R2 was located at 13901 White Tail Run, Brighton Township. The sound level meter was centrally located in the front yard. This location is approximately 1.48 miles N/NE of the clubhouse.

R3 Location R3 was located at 28675 Dixboro Road, Green Oak Township. The sound level meter was located on the north end of the house, at the end of the driveway. This location is approximately 1.22 miles S/SE of the clubhouse.

R4 Location R4 was located on the Island Lake Recreation Area Shooting Range site, between the Clubhouse and the Trap and Skeet Range.

R5 Location R5 was located at the Kensington Metropark Golf Course. The meter was chained to a tree on the north edge of the fairway. This location is approximately 0.58 miles N/NE of the clubhouse.

R6 Location R6 was located at the Kensington Metropark Nature Study Area Trails. The meter was chained to a tree off the trails. This location is approximately 1.06 miles N/NE of the clubhouse.

R7 Location R7 was located at 62500 Silver Lake Road, Lyon Township. The sound level meter was centrally located in the backyard. This location is approximately 0.91 miles SE of the clubhouse.

THE MEASUREMENT TIMES

Acoustical measurements were made from June 3 to June 21, 2008. The dates were selected by DNR staff as a time when representative activities at the ranges could be observed and measured. June 3, 2008 and June 10, 2008 were also on days when the ranges could be closed to the public and controlled shooting could be conducted for the sound assessment.

June 3, 2008

Sound level meters at Locations R1, R2, R3, and R4 were set to sample every 100-milliseconds for the various Range Studies conducted on June 3, 2008. The approximate times within which guns were fired during the studies are included in Table 1.

Table 1. Measurement times of studies conducted on June 3, 2008.

Study	Approximate Time
Sporting Clay Range Study	10:40 AM - 11:40 AM
Trap and Skeet Range Study	11:59 AM - 12:10 PM
Rifle and Pistol Range Study	1:55 PM - 2:17 PM

June 3, 2008 to June 9, 2008

Sound level meters at locations R1, R2, R3, and R4 were set to record 1-minute average sound levels from 12:00 AM to 12:00 AM (24 hours) for 6 days.

June 9, 2008 through June 17, 2008

Sound level meters at locations R5, R6 and R7 were set to take 1-minute average sound level measurements from June 9, 2008 to June 17, 2008.

June 10, 2008

Sound level meters at Locations R1, R2, R3, and R4 were set to sample every 100-milliseconds for the various Range Studies conducted on June 10, 2008. The approximate times within which guns were fired during the studies are included in Table 2.

Table 2. Measurement times of studies conducted on June 10, 2008.

Study	Approximate Time
Sporting Clay Range	11:19 AM - 11:51 AM
Audio Recordings	12:42 AM - 2:13 PM
Shotgun Directionality and Sporting Clay Shed Insertion Loss	2:44 PM - 4:16 PM
Rifle and Pistol Range Overhead Baffle Insertion Loss	4:49 PM - 5:24 PM

June 11, 2008 through June 20, 2008

Sound level meters at locations R1, R2, R3, and R4 were set to take 1-second average sound level measurements from 9:00 AM to 9:00 PM from June 11, 2008 to June 20, 2008.

June 21, 2008

Sound level meters at locations R1, R2, R3 and R4 were set to sample every 100-milliseconds during the competition shooting. Meters at locations R5, R6, and R7 were set to take 1-minute average sound level measurements during the competition shooting.

INSTRUMENTATION

Four types of acoustical measurements were made during this Sound Assessment and Analysis. These are described below.

1. **Long term measurements of average sound levels in the community.** Long term measurements of average sound levels in the community were made with four Larson Davis 831 sound level meters positioned at Locations R1, R2, R3, and R4 from June 4, 2008 to June 8, 2008 and three Rion NL-32 integrating sound level meters positioned at Locations R5, R6, and R7 from June 9, 2008 to June 16, 2008 and on June 21, 2008. The Rion and Larson Davis equipment meets ANSI requirements for Type 1 sound level meters. The meters were set to the fast, A-weighted mode to acquire data. The equipment was calibrated with a Larson Davis CAL200 calibrator before and after testing. The microphone was covered with a wind screen and positioned atop an extension rod or tripod approximately 5 ft 6 inches to 7 ft above ground. The meters were located inside weather proof environmental cases secured to a tree or fence as was available at each site. The meters were set to log 1-minute A-Weighted Continuous Equivalent Sound Levels (LAeq), A-Weighted Maximum Sound Levels (Lamax) and A-Weighted Minimum Sound Levels (LAmin). Graphs illustrating these sound levels are plotted vs. time for each time period are shown in Appendix D. Data were downloaded from the meters memory card to a laptop computer after the measurement time.

   The sound level meter also recorded peak sound level data and statistical acoustic data (L05, L10, L50, L90 L95 and SEL). These data are available for review if required. The L05 is the sound level exceeded for 5% of the measurement time. The L10 is the sound level exceeded for 10% of the measurement time. The L50, L90 and L95 are defined similarly for 50%, 90% and 95% of the measurement time respectively. The SEL is the sound exposure level.

2. **Long term measurements of short duration sound levels in the community.** The four Larson Davis 831 sound level meters at Locations R1, R2, R3, and R4 were also set to log 1-second LAeq overall and octave band sound levels from 9 AM to 9 PM from June 11, 2008 to June 20, 2008. A comparison of the times at which gunshots occurred on site as clearly identified in the meter located at R4 on site with sound levels measured at the same time, adjusted for the delay with distance, at Locations R1, R2, and R3 provides information regarding the typical daily gunshot sound levels at these locations.

3. **Short term measurements of specific acoustic events during controlled Range studies described in Appendix A.** The four Larson Davis 831 sound level meters positioned at locations R1, R2, R3, and R4 were used as the basic instrumentation for the controlled studies on June 3, 2008 and June 10, 2008, and were also used to record short term measurements of gunfire during the competition on June 21, 2008. The meters were calibrated with a Larson Davis Model CAL200 calibrator prior to and after testing. The microphone was positioned on the manufacturer's environmental tripod stand approximately 7 ft above ground. The meter was placed in a weatherproof box and attached to the microphone via an extension cable. A weatherproof windscreen was attached to the microphones for all measurements. Data were stored on the meter hard drive and downloaded to a desktop computer in our office and analyzed.

   The periods of time over which sounds are averaged as the levels are recorded is an important variable to consider when sounds of short duration such as gunshots are of interest. A short duration, transient sound is followed by a brief period of quiet, then a second sound is heard, then another period of quiet occurs, and so on. The loudness of the transient sound is averaged with the period of quiet between the sounds in typical acoustical measurements. Typical sound level meters will record sound levels of short duration sounds at 10-20 dB less than the true peak level of the sound if longer averaging times are used. Therefore when recording gunshots, a very short measurements duration setting on the sound level meter can be used to record the instantaneous sound level that is reached in that period of time. For this reason, the meters were set to log overall and octave band LAeq data every 100-milliseconds. This is similar to measuring an instantaneous sound pressure level with a meter set to a fast setting, only it allows one to pick out very short duration events, such as gunshots that may be mixed in with other sounds that are likely to occur in close proximity to the gunshot sound at similar levels. The LAeq sound levels reported for all of the controlled range studies and experiments represent the LAeq for the 100 millisecond period during which the gun was fired. This value is essentially equivalent to the LAmax or instantaneous sound pressure level with a fast time constant.

4. **Short term measurements of specific acoustic events during controlled directivity and insertion loss experiments described in Appendix A.** A CESVA 310 Real Time Analyzer was used as the basic instrumentation for the directivity and insertion loss experiments conducted on June 3, 2008. The Cesva equipment meets ANSI requirements for Type 1 sound level meters. The meter was set to the acquire 1-second and 1/8 second one-third octave band LAeqs for the entire measurement period. The equipment was calibrated with a Larson Davis CAL200 calibrator before and after testing. The microphone was positioned atop a tripod at a height of approximately 5'-6" above ground for all measurements and attached via a microphone extension cable to the meter, which was held in the Consultants hand at a distance of approximately 20 ft from the microphone so as not to affect the measurement. A windscreen was attached to the microphone for all measurements. Data were stored on the meter's hard drive and downloaded to a desktop computer in our office and analyzed.

Descriptions of Acoustical Terms

1. An A-weighted sound level is one to which an A-weighting filter has been applied to the individual octave bands prior to summing the octave band values to achieve the overall sound level. The A-weighting filter approximates the response of the human ear to lower and medium frequency pure tone

sounds. It deducts significant amounts of sound energy from the low frequencies. Lower frequency or bass sounds are decreased by substantial amounts by the A-weighting process.

2. An octave band is a group of frequencies where the highest frequency is twice the lowest frequency. For example, the octave band centered at 250 Hz, which is approximately middle C on a piano, would span from 177 Hz to 355 Hz, a doubling of frequency. Octave band or one-third octave band sound levels provide the most precise way to measure sounds to describe not only their loudness, but also their pitch. It is possible to present graphs showing several sounds compared to the ambient in a way that demonstrates why sounds with similar overall levels can be heard as different from one another due to the differences in the frequency content or pitch of the sounds.

3. The Leq, or equivalent continuous sound level, is the level of a steady state sound that, over a stated time period, has the same sound energy as the actual time-varying sound. It is also often referred to as the average sound level. The LAeq is the A-weighted equivalent continuous sound level.

4. The Lmax, or maximum sound level, is the maximum sound level that occurs during a given measurement interval. Similarly, the Lmin, or minimum sound level, is the minimum sound level that occurs during a given measurement interval. Overall maximum or minimum sound levels that have the A-weighting filter applied are referred to as LAmax and LAmin sound levels.

SUMMARY OF FINDINGS

SUMMARY OF FINDINGS FROM STUDIES ON WEATHER EFFECTS ON LONG RANGE OUTDOOR SOUND PROPAGATION

Documentation in the technical acoustical literature, recent research conducted and published by the University of Mississippi Department of Mechanical Engineering, and environmental noise studies conducted by Siebein Associates, Inc., indicate that temperature gradients and wind can have a 10 to 15 dB effect on sound compared to "neutral" atmospheric conditions.

During most days, as the sun heats up the surface of the earth, the air temperature near the ground is warmer than the air temperature at higher elevations. This has the effect of bending sound waves upward (away from the warmer air) due to differences in the speed of sound in air of different temperatures, resulting in lower sound levels, as much as 10 dB compared to neutral conditions, at distant (over 1,000 ft) receivers. During temperature induced inversions, the air at higher elevations is warmer than the air at lower elevations. This typically occurs during evening hours when the sun goes down and the earth's surface cools very quickly, also cooling the air close to the ground quickly. It can also occur over cold lakes, during periods of cloud cover that allow the earth to cool down quickly, and during periods of high air pressure, which can last for several days. Local topographical formations can also enhance inversions, especially in valley locations. During these inversions, the sound bends back down towards the earth (away from the warmer air aloft), thereby increasing sound levels, sometimes as much as 10 dB compared to neutral conditions and 20 dB compared to temperature lapse conditions, at distant receivers.

Wind can also effect sound levels at distant receivers, with receivers downwind experiencing higher sound levels and receivers upwind experiencing lower sound levels, compared to periods of little or no wind.

The technical acoustical literature does not contain specific changes in sound level at specific wind speeds, however, project experience and some information from the literature suggests that the effects could be as much as +/- 5dB.

Higher sound levels measured by other consultants during fall and winter months, than those measured by Siebein Associates, Inc., in June, may be attributable to the greater presence of temperature inversions that tend to occur during the cooler months, as well as a loss of foliage on the trees. Wind also plays an important role, as residents have experienced higher sound levels during periods of strong winds in the direction of their residence.

SUMMARY OF FINDINGS FROM CONTROLLED STUDIES AND EXPERIMENTS AT THE ISLAND LAKE SHOOTING RANGE

Please refer to Appendix A for detailed descriptions of the methods, results, and conclusions from the Controlled Studies and Experiments conducted at the Island Lake Shooting Range on June 3, 2008 and June 10, 2008.

1. **Sound levels from guns fired during the Sporting Clay Range studies were measured at levels of 44 to 64 dBA at residential receiver locations approximately 1 to 1.5 miles north (R1 and R2) of the Ranges and 46 to 61 dBA at a residential receiver location approximately 1.25 miles south/southeast of the Ranges (R3).** At times these levels exceeded the ambient sounds by as much as 10 to 20 dB. Sound levels from Trap and Skeet activities measured at Locations R1 and R2 were in the 43 to 54 dBA range sound levels from the Rifle and Pistol Range activities were in the 46 to 62 dBA range. Under acoustically adverse weather conditions these levels could increase by as much as 10 to 15 dB more.

2. **Sound levels measured at distant residential receiver locations (R1, R2, and R3) from guns fired during the Competition on Saturday, June 21, 2008 were significantly higher than those measured during the controlled studies.** Of the 400 shots fired during the controlled studies, only four exceeded 60 dBA, and the highest was 64 dBA. In contrast, during a typical half hour during the afternoon of the Competition, sound levels from guns measured at Location R3 were routinely above 60 dBA, with several shots as high as 70 to 75 dBA. The increased sound levels were likely a result of the increased wind in the direction of location R3, shooters possibly using target loads with more powder (3-1/4 drams, for example, vs. 2-3/4 drams), and simultaneous gunshots from more shooters that would add together within the 0.10 second measurement period.

3. **An analysis of the actual data measured on site under controlled experimental conditions, and computer models constructed of the effects of berms, partial enclosures, digging down into the site, and building barrier walls on top of existing berms indicate that only a minor reduction (0 to 3 dB) in sound can be expected from these types of sound reduction options due to the large distances between the sound source and the affected receivers.** Given the magnitude of the gunfire sounds on the residents and the costs associated with these types of solutions (on the order of $500,000 to over $1 million per improvement) they may not prove to be cost effective.

4. **The direction the shooter is facing is one of the primary factors that determines sound levels from the Shooting Range activities at the remote residential receiver locations. Differences of 20 to 25 dB from the front of the shooter to the rear of the shooter are common at the range.** Sounds from guns pointing in the general direction of receiver locations were audible and identifiable in the data, whereas sounds from guns pointed in the direction away from receiver locations were not audible or identifiable in the data. The results from the shotgun directionality experiment indicate that sound levels behind the shooter are 18 dB lower than those in front of the shooter even without the partial shed enclosure, which likely accounts for an additional 5 dB reduction at longer (over 1 mile) distances. This, combined with the presence of relatively large berms positioned behind the shooters in close proximity to the shooters, results in sound levels that are as much as 20 to 25 dB less behind the shooter compared to in front of the shooter.

5. **Atmospheric and weather conditions also contribute significantly to the sound levels from Shooting Range activities measured at remote residential receiver locations.** Differences as large as 12 dB were observed between measurements made on June 3, 2008 and June 10, 2008 at the same receiver location and with the same source. This occurred with only minor changes in atmospheric conditions. During the Competition on June 21, 2008, sound levels in the afternoon at Location R3 after the wind had shifted towards the south were as much as 10 dB louder than the loudest sounds measured on either June 3, 2008 or June 10, 2008.

6. **Sound levels from Sporting Clay Range activities measured at the residential receiver location (R3) approximately 1-1/4 miles to the southeast of the site were typically higher than those measured at the residential receiver locations to the north (R1 and R2) of the site at a similar distance.** The orientation of shooters and berms on the site, topography between the Range and the receiver locations, and prevailing atmospheric conditions contribute to this difference.

7. **Only sounds from the south, southeast, and southwest facing Sporting Clay stations could be heard and identified in the data at the southeast receiver location (R3).** Conversely, only sounds from the north, northeast, and northwest facing Sporting Clay Stations could be heard and identified in the data at the north receiver locations (R1 and R2)

8. **Sound levels from the Trap and Skeet Range and Rifle and Pistol Range activities were louder at residential receiver locations to the north than to the south due to the direction of gunfire for these ranges and the presence of the 42 foot high berm behind the shooters.** At the residential receiver location to the southeast of the site, gunshots from the Trap and Skeet Range and the Rifle and Pistol Range were inaudible and not identifiable in the data.

9. **Effects of the horizontal direction of the shotguns on distant receiver sound levels.** Sound level differences from 0 dB to 13 dB were obtained between shots that were fired to the left and shots that were fired to the right. The lesser differences occurred where the centerline of the station in the direction of fire was more in line with the receiver location, such as at station S, which points directly towards receiver Location R3. Greater differences occur where the receiver location is much more off axis, and only one of the two directions fired is in line with the receiver location, such as at location O, where only shots fired to the left (southeast) are in the general direction of receiver Location R3.

10. **Effects of the vertical angle of the shotguns on distant receiver sound levels.** The difference in sound levels measured at receiver Locations R1, R2, and R3, between shots fired level with the ground and shots fired more vertically was generally +/- 1 to 3 dB, with occasional differences as high as +/- 6 to 7 dB, with the sound level of the level shot actually exceeding the sound level of the more vertical shot on more occasions (33 vs. 25). These differences are likely to be within the range of variability that could be attributable to the effects atmospheric conditions would have on individual gunshots traveling distances of over a mile. Therefore, it appears that the vertical position of the shotgun relative to the ground, within the range of angles one would use for sporting clay target shooting, does not have a significant effect on the level of the gunshot sounds measured at large distances (over 1 mile) from the shooter.

11. **Changing the target presentation without changing the shed location or orientation is not likely to result in significant reductions in sounds propagated to residential receivers to the north or south of the Range.** Reductions in sound experienced at one residence by changing the horizontal location of the target will just result in increases at another residence that will be more in the direct line of fire. It is not until the shots are fired more in an east or west direction that the sound levels to receivers on the north and south sides will experience noticeable reductions in sound levels.

12. **The effects of the sporting clay partial shed enclosures on receiver sound levels.** Sound levels measured at Locations R1, R2, and R3 in directions that were behind specific sheds were inaudible and not measurable in the data, whether the shooter was inside the shed or outside the shed. Therefore, the extent to which the sheds provide insertion loss in the direction behind the shooter at large distances (over 7,000 ft) could not be determined. The results of the insertion loss experiments on the sheds indicate that at shorter distances (75 ft), the sheds provide an 18 dBA insertion loss.

    Sound levels measured at Locations R1, R2, and R3 when in the general direction of gunfire from specific sheds were between -2 and +4 dB when the shooter was outside the shed compared to when the shooter was inside the shed. This is likely to be within the range of variability that could be attributable to the effects atmospheric conditions would have on individual gunshots traveling distances of over a mile, and therefore it appears that the sheds may not have any significant effect on the level of sounds propagated in the forward direction relative to the shooter at large distances. This is confirmed by the insertion loss experiment on the shed, which showed changes of 0 to 1 dB in the direction of the line of gunfire, which is within the typical range of variability of shotgun sound levels from one shot to the next.

13. **The construction of tall berms or barrier walls around the ranges and downrange of the shooters provide only a 0 to 3 dB insertion loss at the large distances between the Ranges and the affected receiver locations.** Computer model studies showed that depressing the north half of the sporting clay range 20 ft and constructing a 40 ft high berm between the shooters and residential receivers to the south provides only a 3 dB reduction in sound levels, which is a perceivable reduction in sound level to people with normal hearing sensitivities. The cost to construct a berm of this magnitude may not be able to be justified given the relatively small acoustical impact it will have. It takes a 10 dB or greater reduction for sounds to be heard as ½ as loud as the previously were by people of normal sensitivities.

SUMMARY OF FINDINGS FROM LONG TERM ACOUSTICAL MEASUREMENTS IN THE NEIGHBORHOODS

Long Term Acoustical Measurements and Results

1. Graphs of sound level vs. time for each of the long term acoustical measurements are included in Appendix D. The graphs have three lines on them showing LAmax, LAeq and LAmin values for each minute of each day on the graph. The LAmax is the maximum A-weighted sound level reached in each 1- minute time period. The LAeq is the continuous equivalent A-weighted sound level in each 1- minute time period. This is the level that a time varying sound would be if it were the same value for the entire measurement period. The LAmin is the minimum sound level during each 1-minute measurement period.

2. The LAeq represents the average sound level for each minute of the measurement and is controlled primarily by birds and insects, distant traffic sounds, and long term continuous sounds such as planes flying overhead or the sound associated with long periods of rain. The average sound levels increase during the daytime, die down at night as traffic subsides on the highway. At Locations R1 (13301 Lashbrook Lane East) and R2 (13901 White tail Run), the sound levels actually rise back up at night, presumably due to the increased sounds of insects.

3. The LAmax values are typically 5 to 10 dB higher than the LAeq values and are controlled by shorter term events such as guns from the Shooting Range, birds chirping, a local car passing by, or someone shouting. These are seen as "spikes" that rise above the ambient sound.

4. The LAmin values represent the quietest instant during the course of each minute when all the sounds that make up the overall sonic environment have died down to their quietest.

5. Day night average sound levels, or LDN's, were calculated for each of the long term measurement locations. The LDN is the average of the sound levels in each hour of the day with a 10 dB penalty added to sounds that occur during the night time hours (10 pm until 7 am).

6. LDNs at each measurement site were determined from the 1-minute average sound levels for each 24-hour period of measurement at the six critical receiver locations during normal use of the ranges between June 4, 2008 and June 17, 2008 and during heavy usage of the ranges on the competition day on June 21, 2008. These data are summarized in Table 4.

Table 4. Day-Night Average Sound Levels.

Site	Day-Night Average Sound Levels (LDNs, in dBA)							
	6/4/08 (Wed)	6/5/08 (Thur)	6/6/08 (Fri)	6/7/08 (Sat)	6/8/08 (Sun)			
R1	52	55	59	58	70			
R2	62	63	65	61	67			
R3	54	54	58	59	59			
R4	69	67	66	69	71			
	6/9/08 - 6/10/08 (Mon-Tu)	6/10/08 - 6/11/08 (Tu-Wed)	6/11/08 - 6/12/08 (Wed-Th)	6/12/08 - 6/13/08 (Th-Fri)	6/13/08 - 6/14/08 (Fri-Sat)	6/14/08 - 6/15/08 (Sat-Sun)	6/15/08 - 6/16/08 (Sun-Mon)	6/20/08-6/21/08 (Tournament)
R5	63	67	61	65	63	64	65	65
R6	59	56	56	66	56	55	55	55
R7	59	57	55	61	56			54

1. Unusually high sound levels occurred at Location R1 on June 8, 2008 just after midnight.
2. Elevated sound levels on 6/12/08-6/13/08 due to a very loud event that occurred early in the morning, perhaps a thunderstorm.

Conclusions from Long Term Measurements

1. **Sound levels measured on the day of the Tournament (June 21, 2008) were higher than those measured during the previous week.** At Location R5, the Golf Course, the level vs. time graphs in Appendix D show that maximum (LAmax) sound levels during typical afternoons when shooting occurs at the Ranges are typically 5 to 15 dB higher than the LAeq, or average sound levels during short periods of time. However, on June 21, 2008, the day of the Tournament at the Shooting range, the LAmax sound levels exceeded the LAeq sound levels by approximately 20 dB for most of the day. Similar results were measured at Location R6, the Nature Trail, and Location R7, a residence near Silver Lake Road.

2. **The data show that there is little difference in the LDNs that occurred on the day of the Tournament (June 21, 2008) versus those that occurred on the previous weekend days at Locations R5, R6, and R7.** Generally a change of 3 dB in the L_{DN} is viewed as a threshold for establishing noise impact.

RECOMMENDATIONS FOR SOUND REDUCTION

1. **A full building enclosure is required for each of the three ranges to reduce the sounds of gunfire to the vicinity of the ambient sound levels at the residential receivers studied to the north and south of the site.** The results of measurements made during the controlled studies and on the Competition day, as well as a review of data contained in reports by other consultants taken during different times of year, indicate that gunfire sounds from the Ranges, under relatively neutral atmospheric conditions (i.e., minimal wind and temperature gradients) typically exceed the ambient

sound levels at remote residential receivers by approximately 5 to 15 dBA, and under acoustically adverse atmospheric conditions (i.e., moderate to high winds, temperature inversions, etc.) and or winter conditions with no foliage on the trees, exceed the ambient sound levels by as much as 20 to 25 dBA or higher. There are no other sound reduction solutions available that can reduce sound of this magnitude to the vicinity of the ambient sound levels in the affected neighborhoods.

Usually reductions of 10 dB, which result in sounds being heard approximately ½ as loud as they previously were heard, are the minimum goal of sound reduction design studies. Five to 6 dB reductions result in a noticeable reduction in sound level to people of normal sensitivities. None of the options studied, other than a full building enclosure, will yield sound reductions close to 10 dB at remote receiver locations.

2. **Eliminating, moving, or rotating as many as possible Sporting Clay Range stations so that they have a more east-west orientation is the only other practical way to achieve significant reductions in sounds from specific stations outside of a full building enclosure.** However, due to site constraints and the location of affected sites to both the north and south of the facility, reorienting more than a select few of the stations may not be possible. Additionally, relocating shooters may present problems for neighbors to the east and west or for shooters facing into the sun to the east or west. The following is recommended (please refer to Figure 3):

    1. Relocate stations A1 through A3 and Station B to the southwest corner of the facility on the opposite side of the Rifle and pistol Ranges. Point the shooters towards the southwest. The Michigan DNR will need to assess the legalities of this change given the presence of the Huron River in the direction of fire.

    2. Eliminate station C.

    3. Relocate station D to the east side and point due west.

    4. Relocate station J to the east side between G and H and point due west.

    5. Eliminate stations K through R on the north side.

    6. Relocate station S to the west side between T and U if possible, and point due east.

    7. Rotate station T to point due east.

    8. Investigate the possibility of moving other stations to increase the number of stations facing east and west. This may possibly include consider moving the entry road and other existing infrastructure items.

    9. Items 1 through 3 above will remove from the direct line of gunfire the primary Sporting Clay stations contributing to the gunshots heard at the residential receivers to the north.

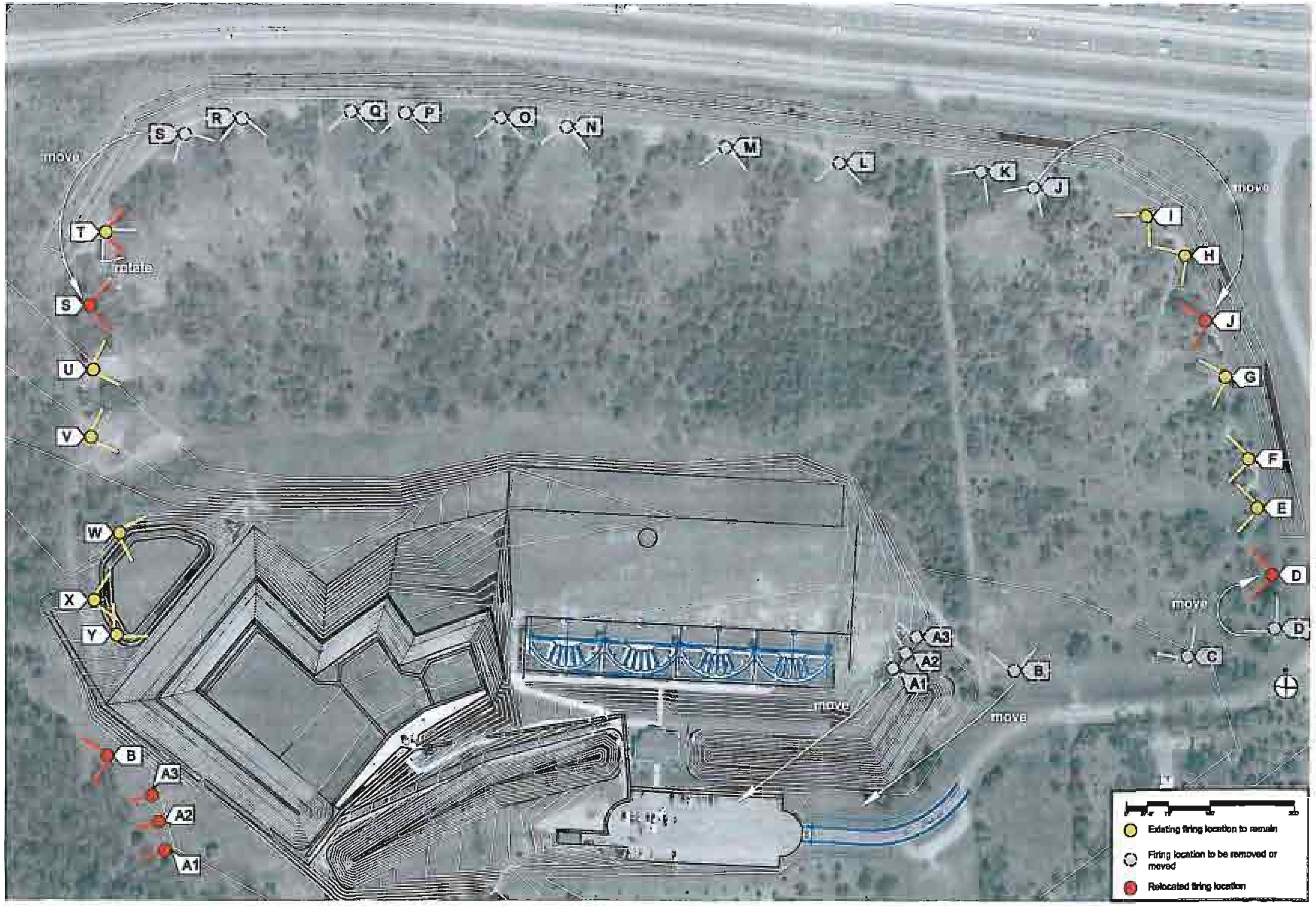

Figure 3. Recommended modifications to Sporting Clay Range stations to reduce off-site sound propagation to residential receivers.

10. Items 4 through 7 above will remove from the direct line of gunfire the primary Sporting Clay stations contributing to the gunshots heard at the residential receivers to the south, to the point where only occasional sounds from off-axis shooting of some of the northernmost sheds may still be audible.

3. **Major earthwork to construct berms and barrier walls at any of the ranges will only provide minor (0 to 3 dB) reductions in sound in the direction of fire at the remote receiver locations and may not be practical given the cost.**

4. **Modifications to the sheds around the shooters are not necessary, as they are providing additional sound reduction to the rear of the shooters without adversely affecting sound levels in the forward direction.**

5. **At the Rifle and Pistol Ranges, consider extending the solid ceiling that is currently over the shooters over the entirety of the overhead baffle system and providing acoustically lined baffled walls between shooter lanes for the entire length of the overhead baffle system (approximately 20 ft).** The underside of the ceiling should also be lined with sound absorbing material. Plan and section sketches along with a more detailed description of this concept are included in Appendix A. It is anticipated that this concept may provide approximately 2 to 4 dB of sound reduction in the direction of residential receivers to the north. If this option is considered, we recommend constructing a mock-up of one or two lanes and having them acoustically tested under a controlled environment before proceeding with this work full scale.

CONCLUSIONS AND FUTURE ACTIONS

Conclusions of the Sound Assessment and Analysis of range activities at the Island Lake Recreation Area Shooting Ranges site are presented below.

1. The number of viable sound reduction options available to the Michigan Department of Natural Resources to reduce gunfire sound levels from the Island Lake Recreation Area Shooting Ranges to the vicinity of ambient sound levels at residential receivers surrounding the facility are limited. This is due to the limited effectiveness of barrier walls and earthen berms to reduce gunfire sounds at large distances when the source of sound is several hundred feet from the berms.

2. The residential receivers to the south of the Shooting Ranges are primarily affected by sounds from the sporting clay stations located along the north side of the facility and facing south or southeast. A combination of relocating some of these stations and eliminating the rest is the only way to reduce the majority of sounds from the ranges to the vicinity of the ambient sounds at the affected residential sites short of constructing a full building enclosure over the stations.

3. The residential receivers on the north side of the Shooting Ranges are acoustically impacted by the Rifle and Pistol Ranges, the Trap and Skeet Range, and the Sporting Clay Range stations located on the south side of the site and facing north. Relocating the sporting clay stations may provide some relief for residents from the gunfire sounds, however, the Trap and Skeet and Rifle and Pistol Ranges will continue to generate gunfire sounds on the order of 5 to 15 dB above the ambient during relatively mild or neutral atmospheric conditions and 20 dB or more during periods of reduced foliage on the trees, wind in the north direction, and temperature inversions. Increasing the height of the existing berms by 20 ft or more could reduce sound propagated into the community by 3 dB or less at a significant cost, and may not be a feasible option.

4. Future action for the DNR to consider includes evaluating the cost effectiveness and practicality of the options presented in this report, including the construction of full building enclosures for the ranges.